

AMENDED SPECIFICATION

Reprinted as amended in accordance with the Decision of the Superintending Examiner acting for the Comptroller-General dated the eighth day of July 1974, under Section 14, of the Patents Act, 1949.

PATENT SPECIFICATION

(11) 1 264 686

DRAWINGS ATTACHED

- (21) Application No. 40021/69 (22) Filed 11 Aug. 1969
(31) Convention Application No. 754 925 (32) Filed 23 Aug. 1968 in
(33) United States of America (US)
(45) Complete Specification published 23 Feb. 1972
(51) International Classification F16k 13/00
(52) Index at acceptance F2V E1B



(54) IMPROVED BUTTERFLY VALVE

(71) We, JAMESBURY CORP., a Corporation organised and existing under the laws of the Commonwealth of Massachusetts, United States of America, of 640 Lincoln Street, Worcester, Commonwealth of Massachusetts, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to rotary valves for the control of fluid flow and more specifically to butterfly valves. In this kind of valve a valve disc or butterfly is mounted in the valve body to rotate about an axis from an open position in which the disc lies parallel to the flow axis to a closed position in which it lies perpendicularly to the flow axis. More particularly, the invention relates to the type of butterfly valve in which a flexible seat is disposed around the periphery of the flow channel for coaction with a sealing surface on the circumference of the butterfly disc when the latter is rotated into its closed position.

Butterfly valves of the type in which a flexible seat projects into the fluid flow channel from the periphery thereof are disclosed in the Hintzman et al. U.S.A. Patent 2,893,682 and the White U.S.A. Patent 2,980,388. Although valves such as this and others known to the prior art are useful in certain types of service, problems of seat life arise in strenuous service from the fact that

the flexible seat is exposed to the high pressures and rapid flow rates that prevail in the fluid stream. During the act of closing the valve, as the butterfly approaches the seat, the erosive effect of fluid rushing with ever-increasing velocity past the flexible seat as the flow area is throttled down accentuates these harmful effects.

Butterfly valves are also employed for throttling service, i.e. service wherein the valve is used to reduce the fluid pressure to some predetermined fraction (not greater than one), of that prevailing upstream. It has been found that butterfly valves are reliable for throttling service at openings such as are provided by rotation of the disc of, approximately, 15° or more from the closed position. At disc positions opened to a lesser extent the valve tends to be unstable due to fluid vortexing. At disc openings substantially greater than 70° from the closed position, virtually full flow is attained. Thus the effective range of disc rotation for throttling is of the order of from 15° to 70° from the closed position, plus or minus about 5°. It is therefore particularly desirable to protect the seat from the erosive forces produced by fluid throttling in this range of disc openings.

According to the invention, there is provided a butterfly valve comprising a valve body of rigid material defining a circular cross-sectional fluid flow channel therethrough, an annular seat affixed by a radially outwardly disposed portion thereof in said valve body to circumscribe said fluid flow channel,

[Price 25p]

Price 75p

said seat having a flexible radially inwardly disposed portion protruding into the flow channel,

5 a shaft aligned non-diametrically across the flow channel at a point axially displaced along said flow channel from the annular seat,

a valve disc mounted for rotation about the axis of said shaft,

10 the circumferential surface of said disc constituting a segment of a continuous geometric surface converging at a point on the axis of the fluid flow channel, said surface constituting a sealing surface adapted to co-operate with the annular seat,

15 the radially inwardly disposed portion of the annular seat having an annular sealing surface adapted to co-operate with said sealing surface on said disc to block fluid flow through the flow channel when the disc is rotated into a closed position perpendicular to the axis of the said flow channel,

20 a second annular surface of said radially inwardly disposed portion of said annular seat, disposed non-colinearly to said sealing surface thereof, exposed to the fluid in the flow channel and adapted to augment the sealing effectiveness of the seat against said disc by the action of fluid pressure,

25 the valve effectively controlling the down stream pressure therethrough at any desired proportion not greater than unity of the fluid pressure prevailing upstream thereof by rotation of the disc about a non-diametric axis of the fluid flow channel to any flow-controlling position at least 15° from its said closed position,

30 and an annular rigid-surfaced ring element axially displaced along the flow channel from the shaft but adjacent said second annular surface of said annular seat, the annular opening of the ring element projecting radially inward to an extent short of intersecting with the locus of rotation of the disc but sufficient to assure that, when the disc is in a flow-controlling position, every point on said sealing surface on that portion of the disc rotated in an axial direction toward the ring element is closer to said ring element than to any portion of said annular seat,

35 the respective extremities of the shaft being mounted in sleeve bearings inserted into cavities in the valve body, the materials from which said sleeve bearings and the flexible portion of the annular seat are formed having a heat-destruction temperature considerably lower than that of the valve body and the disc,

40 the wall thickness of the sleeve bearings being substantially the same as the clearance between the locus of rotation of said disc and said ring element,

45 whereby substantial sealing effectiveness would be retained by the valve in the event of heat damage thereto.

50 Valves of the kind to which the invention relates are desirably assembled and dis-

assembled and the operative components are held in working relationship to each other by means which do not facilitate the creation of fluid leak paths, in which it is unlikely for components to work loose and enter the fluid stream thereby posing a hazard to other components of the fluid flow system such as pumps, gauges and the like, and wherein the forces imposed by the internal fluid pressure upon working components are transmitted to the bearing surfaces designed to resist them efficiently and without creating stress concentration points in elements not well capable of resisting such concentrations.

Another problem frequently encountered with butterfly valves of the type described known from the prior art stems from the fact that fluid pressure acting on the bottom of the shaft is essentially unopposed by fluid pressure acting upon any other surface in the opposite direction and thus creates a resultant upward force upon the shaft. With the butterfly rigidly attached to such shaft any upward movement of the shaft created by such unbalanced force results in the removal of the butterfly from its position of optimum co-operation with the flexible seat.

Where a valve is employed to control the flow of flammable fluids it is highly desirable that its structure permits it to provide at least a relatively effective seal even if the valve has been exposed to quite high temperatures, such as would prevail during a fire. Otherwise the fire, which tends to char and destroy the flexible seat and other organic elements of a valve, may release the flow of the flammable fluid and thereby increase the ferocity of the fire.

In valves of the kind to which the invention relates, the necessity for projecting the radially inwardly portion of the annular seat into the flow channel creates a situation where the seat is readily subjected to excessive wear conditions. Inasmuch as it is required, in valves of this kind, that surfaces of the seat which are non-colinear with the sealing surface thereof be exposed to the fluid stream so that the fluid pressure may enhance the sealing effectiveness of the seat, it is not possible to protect the seat by disposing all but the sealing surface thereof within the valve body and out of the flow channel as is done for instance in the valve disclosed by Bryant in U.S. Patent 3,000,609.

If, in such valves, an annular rigid-surfaced ring element is disposed upstream of the seat, it is desirable that this element extend radially inward as far, or at least nearly as far, into the fluid stream as the radially inward-most segment of the seat itself. Thus, the annulus of the said ring element should not be substantially larger than that of the seat. The thus-placed ring element will materially reduce the deleterious effect of direct impingement by the rapidly flowing fluid upon the portion of

75

80

85

90

95

100

105

110

115

120

125

130

the seat projecting into the flow channel. By proper control of the relative axial displacement of the ring element upstream of the seat and the relative annulus openings of the element openings of the element and the seat, the seat can be located in the *vena contracta* of the flow channel as formed by the ring element. It is widely understood that substantially lower fluid pressures prevail in a *vena contracta* region than in the bulk of a fluid stream. The ring element may also serve to protect the seat from direct high velocity impingement by particles which may be entrained in the fluid stream. Where a butterfly valve embodying the invention is to be used in service in which fluid flow may alternatively occur in either direction, a ring element of the type described is employed on either side of the seat. In this way, the seat is provided with the kind of protection described above from whichever ring element happens to be in the upstream location. In addition, this feature of the invention may be used to protect the seat during throttling of the fluid stream where ring elements upstream and downstream of the seat are employed.

Thus, in accordance with the invention, a second ring element may be positioned on the opposite side of the seat from the first ring element.

Where the nature of the fluid flowing through the valve is such that solid particles may collect on the sealing surface of the butterfly disc, these particles will tend to damage the flexible seat when the valve is closed.

The invention therefore provides a butterfly valve of the type described above, wherein an angular lip is formed at the circumference of the first said ring element closest to the locus of rotation of the disc, said lip being adapted to scrape solids accumulated on the circumferential sealing surface of the disc as the disc is rotated past the lip towards the annular seat.

When the valve is employed to throttle the fluid stream, fluid passes through a flow channel of considerably smaller cross-sectional area than when the valve is set for full flow. The attendant increased linear fluid velocities impose highly erosive forces upon the surfaces which bound this reduced cross-sectional area. Thus, where throttling occurs between the sealing surface of the disc on the one hand and the seat on the other hand, these erosive forces act upon the flexible seat. Where rigid surfaces are projected into the fluid flow channel on either side of the seat so that these rigid surfaces are closer to the sealing surface of the disc when the disc is in a throttling position (i.e., approximately, 15° or greater from the closed position) these surfaces will form the boundary of the reduced cross-sectional area flow channel, thereby diverting the erosive throttling forces from acting upon the seat. It will be apparent from a consider-

ation of the geometry of valves of this kind that at any throttling position of the disc two points on the circumference of the seat must necessarily be closer to the sealing surface of the disc than any point on the respective ring elements, so that the aforesaid protective feature of the invention can not be made to apply to all portions of the circumference of the seat simultaneously. However, the two thus unprotected points on the circumference of the seat will be in a different location on the seat for every different throttling setting of the disc, so that any deleterious effect is ameliorated by being distributed about the circumference of the seat during typical use of a valve.

In a butterfly valve according to the invention, wherein the circumferential sealing surface on said disc falls away sharply from the annular seat when the disc is rotated out of its closed position about the axis of the non-diametrically aligned shaft,

two segments of said rigid wall may be axially displaced from, but proximate to, said annular seat and on either side thereof projecting radially inwardly to an extent sufficient that when the disc is in a flow-controlling position, said sealing surface on said disc — at all but two locations along the circumference thereof — is closer to said rigid wall than to any portion of said annular seat,

whereby, over all but two locations around the circumference thereof, said annular seat is protected against erosive forces acting on a surface which bounds the narrowest segment of the flow path of a turbulently flowing fluid, the erosive forces acting instead on said rigid wall.

The ring elements should not project into the flow channel so far as to intersect the locus of rotation of the disc. However, it is desirable that the annulus of the ring elements should come as close as possible to this locus. If the diameter of the annulus of the ring element is sufficiently small to ensure that every point (with the exception of two small polar segments) on that portion of the circumferential sealing surface of the disc which is rotated toward that particular ring element (as opposed to that portion of the circumferential sealing surface which is rotated toward the other ring element) in opening the valve is closer to that ring element than to any portion of the flexible seat, protection of the seat during fluid throttling will be attained. It will also be apparent to one skilled in this art from a consideration of this specification and its accompanying drawing that protection of the seat can also be realized without providing fully circumferential annular ring elements, but by employing rigid-walled projections suitably disposed into the fluid channel.

Protection of the radially inwardly projecting flexible seat required in valves of the kind referred to against other forms of damage

70

75

80

85

90

95

100

105

110

115

120

125

130

is also possible in constructions embodying the invention. Thus, closing of the valve when the disc has been displaced in the direction along the axis of the shaft would tend seriously to mar or gall the seat. Likewise, rotating the disc fully about its axis of rotation can cause such harm. This latter danger exists especially in valves of the type wherein the disc is mounted for rotation about an axis other than a diameter of the disc. Such non-diametric mounting of the disc for rotation is especially desirable where the circumferential seating surface is a continuously converging surface, such as a segment of a sphere having its center on the axis of the flow channel through the valve, or a frustum of a cone having its apex on the same axis. One reason for mounting discs having such circumferential sealing surfaces nondiametrically is that, when rotated, the circumferential sealing surface on such a disc moves away from the seat at all points along the circumference thereof, rather than scraping across the seat during each opening and closing.

It can readily be appreciated that the full rotation of such a non-diametrically mounted disc could seriously damage the seat.

According to a further feature of the invention, therefore, a plurality of lugs, projecting into the fluid flow channel from the valve body, prevents rotation of the disc substantially beyond a quarter-turn rotation from its fully closed position to its fully open position, whereby to avoid damage to the annular seat in the event of rotation of the non-diametrically mounted disc in the wrong direction.

The lugs may be positioned to interfere with the displacement of said disc along the direction of the axis of said shaft, thereby avoiding damage to the annular seat which might be caused by seating of the disc when improperly positioned along the said direction.

The lugs may be distributed about the shaft so that at least one lug interferes with said displacement in each of the two said directions of the axis of said shaft, regardless of the rotational position of the disc.

Rigid attachment of the disc to the shaft for rotation therewith is also considered a desirable feature of the design of such valves, since this aids precise positioning of the disc with respect to the seat, whereby the valve will not be subject to seat damage due to improper co-operation between the circumferential sealing surface of the disc and the seat.

The invention therefore provides a butterfly valve of the type previously recited, wherein said disc may be formed integrally with a gudgeon, a shaft bore through said gudgeon, and means for affixing the shaft passing through said shaft bore to the disc from one face of said disc only, whereby the valve is devoid of any potential leak path from one face of

the disc through the disc to the other face of said disc.

The said means may include at least one tapered hole passing substantially parallelly to the plane of the disc through the wall of the gudgeon and intersecting the shaft bore and into which a tapered pin may be inserted so that when the disc, the shaft and a tapered pin are assembled a majority of, but less than the entire circumference of, said tapered pin passes through said shaft. In this manner, the pin compresses the shaft against the opposite side of the shaft bore rather than being placed in shear at both surfaces where it enters and leaves the shaft, as would be the case if the pin passed centrally through the shaft.

A special advantage of the instant invention is that it may be employed in the design of butterfly valves for so-called "fireproof" service. Ordinarily, butterfly valves fail when subjected to temperatures at which the organic components thereof, such as the seat and possibly portions of the bearings lose their structural properties. This temperature may be referred to as the heat destruction temperature. By mounting the shaft of a valve embodying the instant invention in bearings having a similar heat destruction temperature to that of the seat and having a thickness of the same order of magnitude as the clearance between the locus of rotation of the disc and the annulus of the ring element, substantially effective metal to metal sealing can be provided between the disc and the ring element in the event of the heat failure of the seat and the bearings, the upstream fluid pressure deflecting the disc and shaft downstream into this metal to metal seating position.

Other features of this invention and the manner of their attainment will be apparent to those skilled in this art from a consideration of this specification — which describes, by way of example only, one particular embodiment of the invention — when taken in conjunction with the accompanying drawing. In the accompanying drawing;

Figure 1 is an elevation of one embodiment of the invention;

Figure 2 is a cross-sectional representation of the same embodiment of the invention as viewed along the plane indicated by line 2—2 in Figure 1;

Figure 3 is a cross-sectional representation, as viewed on the plane indicated by line 3—3 on Figure 2, of several features of the same embodiment of the instant invention; and

Figure 4 is a somewhat schematic cross-sectional representation of the same embodiment of the instant invention illustrating the principle of its operation, the valve disc when being opened to a throttling position being shown by phantom lines.

As may best be seen in Figures 1 and 2, a valve body 10 defines by its internal walls

65

75

80

85

90

95

100

105

110

115

120

125

11 a fluid flow channel 12 having an axis 13. The valve housing is formed of stainless steel, but may be formed of any suitable material of construction as for instance an appropriate metal.

The valve body 10 has cavities 14 and 15 disposed therein, colinearly aligned at opposite ends of flow channel 12. As may best be seen in Figure 1, the axis 16 of these cavities is displaced slightly from the diameter 17 of the flow channel. Therefore this axis, and the axis of a shaft 20 which is mounted in these cavities, extends in the manner of a secant other than a diameter, or non-diametrically, across the fluid flow channel.

Shaft 20 extends transversely across fluid flow channel 12, perpendicular to the axis 13 thereof. Upper and lower shaft bearings 21 and 22, respectively, are disposed in cavities 14 and 15, respectively. These bearings are sleeve bearings and are made of Teflon*-impregnated perforated stainless steel; similar self-lubricating plastic-metallaminates provide examples of other suitable material. The thickness dimension of these bearings is carefully controlled to provide the fire-proof valve feature discussed elsewhere in this specification and is controlled so that the wall thickness of the sleeve bearings is substantially the same as the clearance between the locus of rotation of the disc and the ring elements that are adjacent the sealing ring.

A disc 30 has parallel, circular faces 31 and 32 and is bounded by a continuously convergent circumferential sealing surface 33. In the embodiment shown, surface 33 is a frustum of a cone having its apex on axis 13 (extended), but other convergent surfaces, such as segments of spheres, may also be used. Formed integrally with disc 30 is a gudgeon 34, having a shaft bore 35 adapted to receive shaft 20 passing therethrough. Tapered holes 36 and 37 pass through the gudgeon parallel to the faces 31 and 32 of said disc. As may best be seen in Figure 3, the holes 36 and 37 pass through gudgeon 34 in such a fashion as to intersect non-tangentially with shaft bore 35 so that when two tapered pins 36p and 37p are placed therein a majority, but not all, of the circumference of said tapered pins will pass through shaft 20, assuring that shaft 20 will be compressed firmly against shaft bore 35. By this arrangement the resultant force of the fluid pressure acting on disc 30 in service is transmitted from the disc directly to shaft 20 (and thence to shaft bearings 14 and 15) without the build-up of stresses at the shear planes where the tapered pins enter and leave the shaft, as would be the case were the tapered pins to pass centrally through the shaft.

*Registered Trademark, E.I. dePont de Nemours and Company for poly-tetrafluoro-ethylen).

Lugs 38 and 38a projecting into flow channel 12 serve to prevent rotation of disc 30 beyond the fully open position. Further lugs 39 and 39a serve to prevent rotation of disc 30 in the wrong direction from the fully closed position. Lugs 38 and 39 also serve to prevent upward displacement of disc 30 along the direction of the axis of shaft 20 and lugs 38a and 39a similarly prevent opposite displacement of disc 30.

An annular seat 40 is fashioned of stiffly flexible material, in this embodiment Teflon (registered Trade Mark) or alternatively other polyfluorocarbon, nylon, polyethylene, rubber, rubber-resin blends or other suitable compositions. The radially outward portion 41 of the seat is embedded in valve body 10. For ease of replacement, this embedding is accomplished by the use of a removable retainer ring 42 which in the valve being described is made of the same metal as valve body 10.

The radially inward portion 43 of seat 40 has an annular sealing surface 44 as well as fluid contacting surfaces 45 and 46. As may better be seen in Figure 4, these fluid contacting surfaces are non-colinear with sealing surface 44. Fluid pressure acting on these fluid-contacting surfaces thus serves to deflect the radially inward portion 43 of seat 40 and thereby enhances the effectiveness of the sealing action between seat 40 and circumferential sealing surface 33 of disc 30.

Rigid-surfaced ring elements 50 and 51 are shown displaced in either direction along the axis of flow channel 12 from seat 40. As may best be seen in Figure 4, these surfaces project radially inwardly close to the locus of rotation of disc 30 without intersecting this locus. Sharply angled lips 50(1) and 51(1) are formed at that circumferential element of each of these surfaces which is closest to the locus of rotation.

As may also be seen in Figure 4, the rotation of disc 30 (as indicated in phantom lines from a fully closed position toward throttling positions creates a condition where disc 30 is closer to surfaces 50 and 51 than to any point on seat 40, so that fluid throttling occurs between the rigid surfaces of disc 30 and rigid surfaces 50 and 51 rather than between disc 30 and annular flexible seat 40. Rigid surfaces 50 and 51, projecting inwardly as far as the locus of rotation of the disc 30 will permit, will tend to place the seat 40 in the *vena contracta* of high velocity flow emanating from their respective directions.

Another problem encountered with many of the valves known to the prior art is that they are capable of resisting fluid pressure from one direction only. Such valves therefore are not effective in service wherein fluid pressure may at different times be exerted upon the valve from either one side or the other side thereof, e.g. for installation in lines where fluid flow is periodically reversed.

5

10

15

20

25

30

35

40

45

50

55

60

65

70

75

80

85

90

95

100

105

110

115

120

125

It will be appreciated that the resilient valve seat itself projects into the fluid passage to a degree that exposes not only the surface that makes contact with the valve disc, but also the two side surfaces leading up to the sealing surface. With particular reference to the lower half of Figure 4, the surface that comes in contact with the disc is designated as 44 while the two side surfaces of the disc are designated as 45 and 46. As has been pointed out in this specification, when surfaces of the seat which are non-colinear (45,46) with the sealing surface (44) are exposed to the fluid stream, the fluid pressure will enhance the sealing effectiveness of the seat. With such a configuration, it is not possible to protect the seat by disposing all but the sealing surface (44) within the valve body and out of the flow channel. As stated in the specification, the non-colinear surfaces of the seat ring are exposed to the fluid so that the fluid pressure may enhance the sealing effectiveness of the seat. Different amounts of area on the respective faces of the flexible seat are exposed to the resultant forces created by internal fluid pressure. The significant area for this purpose is the projection of the actual area of the seat exposed to this pressure projected upon a plane normal to the flow axis of the valve. As shown in Figure 4, face 46 of the sealing ring presents a considerably larger face to fluid than face 45. When the valve is fully closed, upstream pressure will press against disc 30. The amount that disc 30 will be displaced is independent of the direction in which fluid pressure is applied to the disc. (This is because the relative motion or displacement of disc 30 is attributable only to the natural flexibility of the shaft, the compressibility of the bearings, etc.). Disc 30 thus deflects isotropically. The valve ring itself, however, undergoes an *anisotropic* deflection under the influence of fluid. More specifically and again with reference to the bottom section of Figure 4, the fluid pressing against face 46 will tend to deflect or push the seat into the disc more than the fluid would tend to deflect the seat when pressing against face 45. As has already been mentioned, the valve disc itself (element 30) will deflect the same amount regardless of the direction of fluid pressure. Consequently, when pressure is applied from the right-hand side of Figure 4, the sealing ring will tend to deflect more than the disc (thereby increasing the sealing effectiveness) and when fluid is applied from the left-hand side of the figure, the sealing ring will tend to deflect less than the disc (again tending to increase the sealing efficiency).

The fact that it is necessary to expose the side surfaces of the sealing ring to the fluid pressure in order to enhance the sealing effectiveness creates the erosion problems that this application is directed to.

WHAT WE CLAIM IS:—

1. A butterfly valve comprising a valve body of rigid material defining a circular cross-sectional fluid flow channel therethrough,

an annular seat affixed by a radially outwardly disposed portion thereof in said valve body to circumscribe said fluid flow channel, said seat having a flexible radially inwardly disposed portion protruding into the flow channel,

a shaft aligned non-diametrically across the flow channel at a point axially displaced along said flow channel from the annular seat,

a valve disc mounted for rotation about the axis of said shaft,

the circumferential surface of said disc constituting a segment of a continuous geometric surface converging at a point on the axis of the fluid flow channel, said surface constituting a sealing surface adapted to co-operate with the annular seat,

the radially inwardly disposed portion of the annular seat having an annular sealing surface adapted to co-operate with said sealing surface on said disc to block fluid flow through the flow channel when the disc is rotated into a closed position perpendicular to the axis of the said flow channel,

a second annular surface of said radially inwardly disposed portion of said annular seat, disposed non-colinearly to said sealing surface thereof, exposed to the fluid in the flow channel and adapted to augment the sealing effectiveness of the seat against said disc by the action of fluid pressure,

the valve effectively controlling the downstream pressure therethrough at any desired proportion not greater than unity of the fluid pressure prevailing upstream thereof by rotation of the disc about a non-diametric axis of the fluid flow channel to any flow-controlling position at least 15° from its said closed position,

and an annular rigid-surfaced ring element axially displaced along the flow channel from the shaft but adjacent said second annular surface of said annular seat, the annular opening of the ring element projecting radially inward to an extent short of intersecting with the locus of rotation of the disc but sufficient to assure that, when the disc is in a flow-controlling position, every point on said sealing surface on that portion of the disc rotated in an axial direction toward the ring element is closer to said ring element than to any portion of said annular seat, the respective extremities of the shaft being mounted in sleeve bearings inserted into cavities in the valve body, the materials from which said sleeve bearings and the flexible portion of the annular seat are formed having a heat destruction temperature considerably lower than that of the valve body and the disc,

the wall thickness of the sleeve bearings being substantially the same as the clearance between the locus of rotation of said disc and said ring element,

It will be appreciated that the resilient valve seat itself projects into the fluid passage to a degree that exposes not only the surface that makes contact with the valve disc, but also the two side surfaces leading up to the sealing surface. With particular reference to the lower half of Figure 4, the surface that comes in contact with the disc is designated as 44 while the two side surfaces of the disc are designated as 45 and 46. As has been pointed out in this specification, when surfaces of the seat which are non-colinear (45,46) with the sealing surface (44) are exposed to the fluid stream, the fluid pressure will enhance the sealing effectiveness of the seat. With such a configuration, it is not possible to protect the seat by disposing all but the sealing surface (44) within the valve body and out of the flow channel. As stated in the specification, the non-colinear surfaces of the seat ring are exposed to the fluid so that the fluid pressure may enhance the sealing effectiveness of the seat. Different amounts of area on the respective faces of the flexible seat are exposed to the resultant forces created by internal fluid pressure. The significant area for this purpose is the projection of the actual area of the seat exposed to this pressure projected upon a plane normal to the flow axis of the valve. As shown in Figure 4, face 46 of the sealing ring presents a considerably larger face to fluid than face 45. When the valve is fully closed, upstream pressure will press against disc 30. The amount that disc 30 will be displaced is independent of the direction in which fluid pressure is applied to the disc. (This is because the relative motion or displacement of disc 30 is attributable only to the natural flexibility of the shaft, the compressibility of the bearings, etc.). Disc 30 thus deflects isotropically. The valve ring itself, however, undergoes an *anisotropic* deflection under the influence of fluid. More specifically and again with reference to the bottom section of Figure 4, the fluid pressing against face 46 will tend to deflect or push the seat into the disc more than the fluid would tend to deflect the seat when pressing against face 45. As has already been mentioned, the valve disc itself (element 30) will deflect the same amount regardless of the direction of fluid pressure. Consequently, when pressure is applied from the right-hand side of Figure 4, the sealing ring will tend to deflect more than the disc (thereby increasing the sealing effectiveness) and when fluid is applied from the left-hand side of the figure, the sealing ring will tend to deflect less than the disc (again tending to increase the sealing efficiency). The fact that it is necessary to expose the side surfaces of the sealing ring to the fluid pressure in order to enhance the sealing effectiveness creates the erosion problems that this application is directed to.

WHAT WE CLAIM IS:—

1. A butterfly valve comprising a valve body of rigid material defining a circular cross-sectional fluid flow channel therethrough, an annular seat affixed by a radially outwardly disposed portion thereof in said valve body to circumscribe said fluid flow channel, said seat having a flexible radially inwardly disposed portion protruding into the flow channel, a shaft aligned non-diametrically across the flow channel at a point axially displaced along said flow channel from the annular seat, a valve disc mounted for rotation about the axis of said shaft, the circumferential surface of said disc constituting a segment of a continuous geometric surface converging at a point on the axis of the fluid flow channel, said surface constituting a sealing surface adapted to co-operate with the annular seat, the radially inwardly disposed portion of the annular seat having an annular sealing surface adapted to co-operate with said sealing surface on said disc to block fluid flow through the flow channel when the disc is rotated into a closed position perpendicular to the axis of the said flow channel, a second annular surface of said radially inwardly disposed portion of said annular seat, disposed non-colinearly to said sealing surface thereof, exposed to the fluid in the flow channel and adapted to augment the sealing effectiveness of the seat against said disc by the action of fluid pressure, the valve effectively controlling the downstream pressure therethrough at any desired proportion not greater than unity of the fluid pressure prevailing upstream thereof by rotation of the disc about a non-diametric axis of the fluid flow channel to any flow-controlling position at least 15° from its said closed position, and an annular rigid-surfaced ring element axially displaced along the flow channel from the shaft but adjacent said second annular surface of said annular seat, the annular opening of the ring element projecting radially inward to an extent short of intersecting with the locus of rotation of the disc but sufficient to assure that, when the disc is in a flow-controlling position, every point on said sealing surface on that portion of the disc rotated in an axial direction toward the ring element is closer to said ring element than to any portion of said annular seat, the respective extremities of the shaft being mounted in sleeve bearings inserted into cavities in the valve body, the materials from which said sleeve bearings and the flexible portion of the annular seat are formed having a heat destruction temperature considerably lower than that of the valve body and the disc, the wall thickness of the sleeve bearings being substantially the same as the clearance between the locus of rotation of said disc and said ring element,



whereby substantial sealing effectiveness would be retained by the valve in the event of heat damage thereto.

2. A butterfly valve according to claim 1 wherein a second ring element is positioned on the opposite side of the seat from the first ring element.

3. A butterfly valve according to claim 1 or claim 2 wherein an angular lip is formed at the circumference of the first said ring element closest to the locus of rotation of the disc, said lip being adapted to scrape solids accumulated on the circumferential sealing surface of the disc as the disc is rotated past the lip toward the annular seat.

4. A butterfly valve according to any preceding claim wherein a plurality of lugs, projecting into the fluid flow channel from the valve body, prevents rotation of the disc substantially beyond a quarter-turn rotation from its fully closed position to its fully open position, whereby to avoid damage to the annular seat in the event of rotation of the non-diametrically mounted disc in the wrong direction.

5. A butterfly valve according to claim 4 wherein the lugs are positioned to interfere with the displacement of said disc along the direction of the axis of said shaft, thereby avoiding damage to the annular seat which might be caused by seating of the disc when improperly positioned along the said direction.

6. A butterfly valve according to any preceding claim wherein said disc is formed integrally with a gudgeon, a shaft bore through said gudgeon, and means for affixing the shaft passing through said shaft bore to the disc from one face of said disc only, whereby the valve is devoid of any potential leak path from one face of the disc through the disc to the other face of said disc.

7. A butterfly valve according to claim 6 wherein the said means includes at least one tapered hole passing substantially parallel to the plane of the disc through the wall of the gudgeon and intersecting the shaft bore and into which a tapered pin may be inserted so that when the disc, the shaft and a tapered pin are assembled a majority of, but less than the entire circumference of, said tapered pin passes through said shaft.

8. A butterfly valve according to any of claims 4 to 7 wherein the said lugs are distributed about the shaft so that at least one lug interferes with said displacement in each of the two said directions of the axis of said shaft, regardless of the rotational position of the disc.

9. A butterfly valve according to any preceding claim wherein at least a portion of the fluid flow channel is bounded by a rigid wall, the radially inwardly disposed portion of the said annular seat forming an annular sealing surface,

and the said annular seat protruding radially inwardly into the fluid flow channel whereby the fluid in the channel contacts a surface thereof which is non-colinear with the said annular sealing surface thereof,

the circumferential sealing surface on said disc falling away sharply from the annular seat when the disc is rotated out of its closed position about the axis of the non-diametrically aligned shaft,

two segments of said rigid wall being displaced from, but proximate to, said annular seat and on either side thereof projecting radially inwardly to an extent sufficient that when the disc is in a flow-controlling position, said sealing surface on said disc — at all but two locations along the circumference thereof — is closer to said rigid wall than to any portion of said annular seat,

whereby, over all but two locations around the circumference thereof, said annular seat is protected against erosive forces acting on a surface which bounds the narrowest segment of the flow path of a turbulently flowing fluid, the erosive forces acting instead on said rigid wall.

10. A butterfly valve substantially as hereinbefore described with reference to and as illustrated in Figures 1, 2, 3 and 4 of the accompanying drawings.

JAMESBURY CORP.

Per: Boulton, Wade & Tennant,
112 Hatton Garden,
London, EC1N 8NA.
Chartered Patent Agents.

